Upgrade of the Hydrodynamic Component of the Navy's Mine Impact Burial Prediction Model (IMPACT28)

Peter C. Chu
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943
phone: (831) 656-3688 fax: (831) 656-3686 email: chu@nps.navy.mil

Award Number: N0001403WR20178
http://www.oc.nps.navy.mil/~chu/noap.html

LONG-TERM GOALS

The long-term goal is to improve performance of the U.S. Navy's mine impact burial prediction capabilities in littoral regions through updating the Navy's existing mine impact burial models (2D with imperfect physics) such as IMPACT28 to 3D mine impact burial prediction model with full physics (IMPACT35). Development of the Navy's new model (IMPACT35) has the NPS students' (U.S. Naval officers) participation as their thesis studies that enhances the Navy's R&D program and well prepares the students with their combat effectiveness.

OBJECTIVES

The specific objectives of the effort include

- To collect and analyze the data of mine drop experiments for model development and evaluation
- To develop a new noise filtering method (i.e., the rotation method) to process the data collected from the mine drop experiments
- To develop the triple coordinate transform scheme for predicting the mine movement in the water column
- To update the hydrodynamic part of IMPACT28 (two dimensional with simplified physics) to IMPACT35, a three dimensional full physics model
- To provide the analyzed data from mine drop experiments to the mine impact burial prediction modeling (IBPM) community
- To deliver the hydrodynamic part of IMPACT35 to the IBPM community
- To integrate the NPS mine impact burial prediction model into the Naval Oceanographic Office mine warfare program for operational use

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Upgrade of the Hydrodynamic Component of the Navy's Mine Impact Burial Prediction Model (IMPACT28)	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,,Department of Oceanography,,Monterey,,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goal is to improve performance of the U.S. Navy???s mine impact burial prediction capabilities in littoral regions through updating the Navy???s existing mine impact burial models (2D with imperfect physics) such as IMPACT28 to 3D mine impact burial prediction model with full physics (IMPACT35). Development of the Navy???s new model (IMPACT35) has the NPS students??? (U.S. Naval officers) participation as their thesis studies that enhances the Navy???s R&D program and well prepares the students with their combat effectiveness.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**7**	

APPROACH

The approach included data analysis and modeling effort and interelated objectives identified in the section above to develop a comprehensive three dimensional mine impact burial prediction model, IMPACT35.

(A) Development of a New Method for Reconstruction of Noisy Data

The data collected from various mine drop experiments with different sizes are quite noisy. To filter out the noises, a new method, the rotation method, has been developed to analyze the noisy data (Chu et al., 2003b). Reconstruction (reproduction from noisy data) of mine movement in the water column is to solve an ill-posed linear algebraic equation,

$$\mathbf{A}\hat{\mathbf{a}} = \mathbf{QY}, \qquad (1)$$

where $\hat{\mathbf{a}}$ is the estimated state vector (L-dimensional) for the exact state vector **a** (such as the velocity and orientation). The algebraic equation (1) is usually ill-posed. The new method was developed to reduce noise through multiplication of (1) by a plane rotation matrix **S** from the left,

$$\mathbf{SA}\hat{\mathbf{a}} = \mathbf{SQY}, \qquad (2)$$

which changes the coefficient matrix and the source term from (**A, QY**) to (**SA, SQY**) and provides the opportunity to minimize the imperfection of the new system (2). The results will be published in the International Journal of Biurfication and Chaos. This method can be used by other principal investigators in the IBPM community.

(B) Development of a New Method for Modeling Mine Movement and Orientation

Triple coordinate systems are introduced to predict translation and orientation of falling mine through the water column (Chu et al., 2003a): earth-fixed coordinate (E-coordinate), cylinder's main-axis following coordinate (M-coordinate), and hydrodynamic force following coordinate (F-coordinate). Use of the triple coordinate systems and the transforms among them leads to the simplification of the dynamical system. The body and buoyancy forces and their moments are easily calculated using the E-coordinate system. The hydrodynamic forces (such as the drag and lift forces) and their moments are easily computed using the F-coordinate. The cylinder's moments of gyration are simply represented using the M-coordinate. The model has been evaluated by the mine experimental data. The new hydrodynamic modeling results will be published in the Journal of Applied Mechanics.

(C) Development of 3D IMPACT35

IMPACT35 is developed from 2D IMPACT28 with new physics and schemes. IMPACT35 keeps all the mine types and their physical parameters as used in IMPACT28, and contains new components of hydrodynamics, new treatments of air-water and water-sediment interfaces. The model contains five types of input: (1) mine types, (2) release medium (air or water), (3) bottom type (profile of shear stress), (4) release kinematics (release angle and rotation rate), and (5) release medium parameters (release altitude, water depth, and water temperature). The output includes: temporally varying position and orientation (3D) in the air, water, and sediment phases, the bottom impact angle, and penetration depth. The computer codes will be written using Matlab with full 3D visualization capability.

(D) Model Evaluation Procedures

Since the new model (IMPACT35) contains new physics and treatments, the model evaluation includes theoretical and experimental procedures. The theoretical evaluation procedure is conducted through the peer-review process of journal articles. The experimental evaluation procedure is conducted through model-data inter-comparison.

WORK COMPLETED

The structure of the new 3D IBPM model with full physics has been constructed from the existing 2D IBPM model with reduced physics (IMPACT28). The model structure is illustrated in Fig. 1. IMPACT35 has three phases (air, water, and sediment) and two interfaces (air-water, and water-sediment.

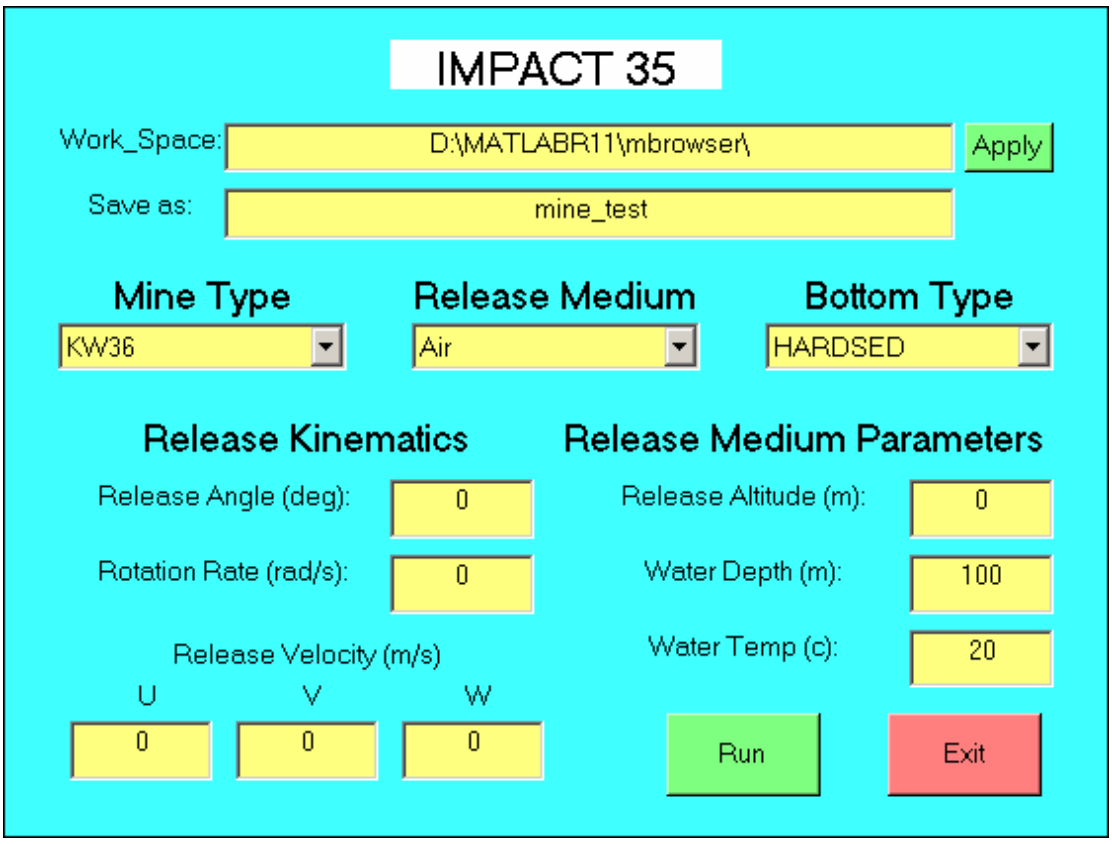

Fig. 1. Illustration of IMPACT35

The hydrodynamic model has been developed and evaluated for the cylindrical mines moving in the water phase using the data collected from the Mine Drop Experiment (MIDEX) conducted at the Naval Postgraduate School (NPS) in July 2001 (Chu et al., 2002).

Triple coordinate transform method was developed and evaluated. This method is the core of the hydrodynamic part of IMPACT35. The theoretical part of the method will be published in the Journal of Applied Mechanics.

The rotation method for noise reduction was developed and tested. The results will be published in the International Journal of Biurfication and Chaos.

RESULTS

(1) The triple coordinate transform method developed in FY03 has wide application to predict the position and orientation of an object falling through the fluid. The model results are shown in Fig.2 for the nose-down mine and in Fig. 3 for the nose-up mine.

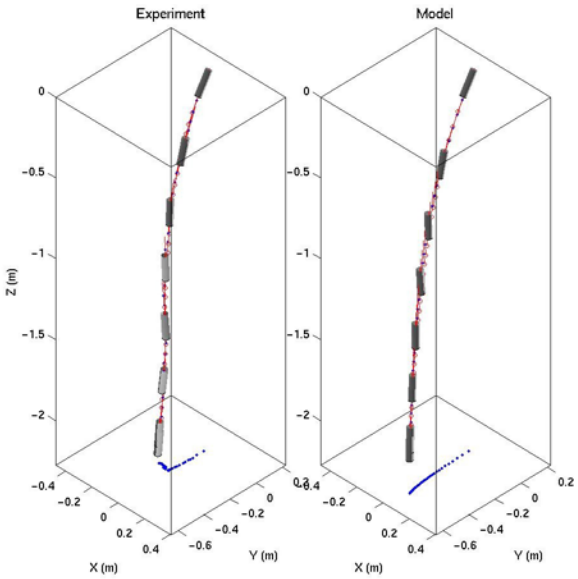

Fig. 2. Model-data comparison for nose-down mine (after Chu et al., 2003a).

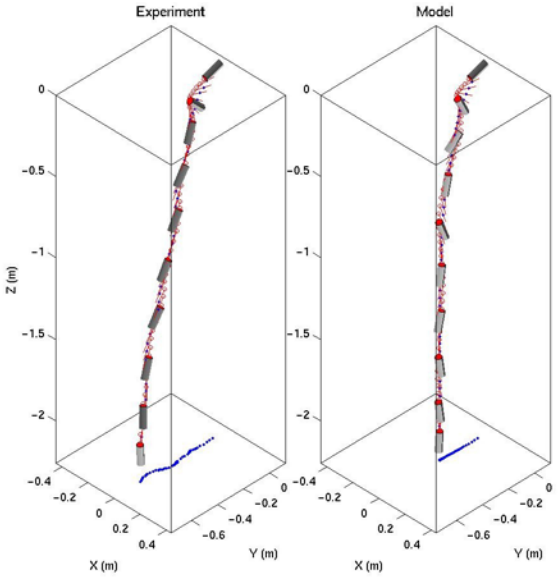

Fig. 3. Model-data comparison for nose-up mine (after Chu et al., 2003a).

(2) The rotation method for noise reduction developed in FY03 can be widely used for reconstructing process and field from imperfect data for many disciplines.

IMPACT/APPLICATIONS

- The dynamic system (nonlinear equations) for the mine movement has the potential impact on the nonlinear dynamics. The hydrodynamics of mine impact in water column can be applied to a general scientific problem of the fluid-rigid body interaction including stability and chaotic motion.

- The hydrodynamic component of IMPACT35 was transferred to the IBPM community such as to Drs. Alan Brandt and Sarah Rennie at the APL Lab in the John Hopkins University.

- The noise reduction scheme (rotation method) will impact the scientific and Naval mine warfare communities on the mine movement in the water column.

RELATED PROJECTS

This project is related to the ONR Expert System program. The results obtained from this project are the basic materials for building the Expert System for mine burial prediction.

THESES DIRECTED

Two students, LT Albert Armstrong and LT Michael Cornelius (both USN) are working on the effects of sediment on mine impact burial for their theses. They will graduate in June 2004.

TRANSITIONS

- The results obtained from this project are transferred to the Naval Oceanographic Office, COMINEWARCOM, and the ONR Mine Impact Burial Prediction group such as the mine expert system and mine scour and liquifaction groups.

- The hydrodynamic component of IMPACT35 was transferred to the IBPM community such as to Drs. Alan Brandt and Sarah Rennie at the APL Lab in the John Hopkins University.

- Hydrodynamic component of IMPACT35 was used for development of the Expert System for Mine Impact Burial at the Applied Physics Laboratory of the John Hopkins University and the Environmental Sciences Department of the University of Virginia.

- The datasets collected from MIDEX ($1/15^{th}$ size), NSWC-Carderock Experiment ($1/3^{rd}$ size), and Corps Christi Experiment (full size) will greatly impact on the development of an accurate Mine Impact Burial Prediction Model.

- The data were also used for development of the Mine Scouring and Liquifaction modeling effort at the Scripps Oceanographic Institution (headed by Dr. Scot Jenkins).

PUBLICATIONS

Chu, P.C., A.F. Gilless, C. Fan, and P. Fleischer, 2002. Hydrodynamical Characteristics of a Falling Cylinder in the Water Column. *Advances in Fluid Mechanics* vol 4, edited by M. Rahman, R. Verhoeven, and C.A. Brebbia, WIT Press, Southampton, UK, 163-181.

Chu, P.C., C.W. Fan, A.D. Evans, and A. Gilles, 2003a: Triple coordinate transforms for prediction of falling cylinder through the water column. Journal of Applied Mechanics, in press.

Chu, P.C., L.M. Ivanov, and T.M. Margolina, 2003b: Rotation method for reconstructing process and field from imperfect data. International Journal of Bifurcation and Chaos, in press.

Chu, P.C., C.W. Fan, A.D. Evans, A. Gilles, and P. Fleischer, 2003c: Three dimensional hydrodynamic model for prediction of falling cylinder through the water column. Proceedings on IEEE/MTS OCEANS2003 Conference, pp.11, in CD-Rom.

Chu, P.C., E. Gottshall, and M. Perry, 2003d: Satellite remote-sensed altimetry Data for Improvement of Naval Undersea Capability, Proceedings on IEEE/MTS OCEANS2003 Conference, pp.11, in CD-Rom.

CONFERENCE PRESENTATIONS

Chu, P.C., C.W. Fan, A. Evans, A. Gilles, and P. Fleischer: Three dimensional hydrodynamic model for falling cylinder through the water column, IEEE/MTS OCEANS2003, September 22-26, 2003, San Diego.

Chu, P.C., E. Gottshall, and M.Perry, Satellite Remote-sensed Altimetry Data for Improvement of Naval Undersea Capability, IEEE/MTS OCEANS2003, September 22-26, 2003, San Diego.